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An Appraisal of Methods for Salvaging Small--Sawmill Residues in the Southeast

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AN APPRAISAL OF METHODS FOR SALVAGING SMALL-SAWMILL RESIDUES IN THE SOUTHEAST

by

A. S. Todd, Jr. and Walter C. Anderson

SUMMARY

Ten possible methods of salvaging pulpable slabs and edging strips from small pine sawmills are presented. A system of cost analysis for determining the cheapest method for a given situation and area is outlined and illustrated.

The various salvage methods are reduced to their component operations such as debarking, chipping, handling, and transportation. Unit cost estimates by volume of output are prepared for each of these components. Summing the component costs in appropriate combinations provides cost estimates for complete salvage methods. In this way, it is possible to determine the lowest cost output of chips for each method and the lowest cost method for any desired output.

Application of the proposed analysis to a typical Piedmont area indicated that the cheapest method of salvaging volumes up to 190 cords per day is by concentrating rough residues at the pulpmill for debarking and chipping. If the volume required exceeds 190 cords, the central operation should be supplemented by rail yards that process rough residues and ship chips to the mill. The smallest economic rail yard is one with a daily capacity of 25 to 30 cords. Although debarking and chipping at centralized points are less expensive than the same operations performed at small sawmills, there may be circumstances under which processing at the sawmill is necessary or desirable. For such cases, the cost analysis showed that if the debarking is to be done at sawmills, money will be saved by chipping the residues there as well.

INTRODUCTION

Sawmill slabs, edging strips, and other residues formerly considered of little or no value are becoming an increasingly important source of wood for pulping in the Southeast. The dollar-per-hour minimum wage and recent increases in the price of roundwood should encourage an even more rapid expansion of the market for wood residues in the near future. However, to date, the development of the slab salvage program has depended primarily on the installation of expensive log barking and chipping equipment at the larger pine sawmills. Little progress has been made in the marketing and utilization of residues at the small pine sawmills that produce three-quarters of all the potentially chippable material.

This report has two purposes. The first is to appraise the practicability and comparative efficiency of various methods for procuring, transporting, and processing the residues in a typical small-mill area. The second is to present a method of cost analysis that can be employed to select for any area the cheapest means of obtaining a desired quantity of pulp chips from small-mill residues.

Since the pulp and paper industry is primarily based on the use of pine, the costs and other data presented herein are intended to apply only to the pine species, pine sawmills, and pine-producing areas of the southern Piedmont. The operating and handling methods described, however, will apply equally well to hardwoods when a market for them develops.

POSSIBLE SALVAGE METHODS

Methods of marketing small-mill residues for pulping can be grouped under two heads: (1) those involving direct shipment to a pulpmill, and (2) those involving assembly and reshipment, with varying amounts of processing, at concentration points located in the lumber (and slab) producing areas. At one time or another, both rough and hand-peeled slabs have been shipped directly to pulpmills in this region. Direct dealing between sawmill and pulpmill also characterizes the marketing of pulp chips produced at the larger sawmills. Concentration yards play a prominent role in the procurement of round pulpwood and the manufacture of lumber, so they may also prove successful in facilitating the procurement of slabwood.

Sawmill residues originate as irregularly shaped pieces in a variety of widths, thicknesses, and lengths. In the rough form, their average bark content ranges from approximately 25 percent by volume for edgings to about 35 percent for slabs. To prepare the residues for pulping, the bark must be reduced to 5 percent or less, and they must be converted to chips of rather uniform length, conforming to the specifications of the purchaser.

With machines now on the market, it is possible to remove the bark either from the logs before sawing or from the slabs and edgings afterwards. If slab barkers are employed, they can be installed at the sawmills, at concentration yards, or at the pulpmill. Chipping offers a similar choice of locations. The sites selected for debarking and chipping should be determined chiefly by the volumes to be handled; by balancing the cost of transporting bark against the greater efficiency of large-scale centralized processing; and by comparing the costs of loading, transporting, and unloading slabs with the same costs for chips.

Based on the alternatives just outlined, there are apparently ten possible methods of salvaging small-mill residues for pulping, as follows:

Direct Shipment from Sawmill to Pulpmill

1. Rough slabs and edgings
2. Slabs and edgings from debarked logs
3. Peeled slabs and edgings
4. Chips from the slabs and edgings of debarked logs
5. Chips from peeled slabs and edgings

Assembly and Reshipment at a Concentration Yard

6. Slabs and edgings, or chips, reshipped in the same form as received
7. Slabs and edgings peeled at yard, chipped at pulpmill
8. Slabs and edgings peeled and chipped at yard
9. Slabs and edgings from debarked logs chipped at yard
10. Slabs and edgings peeled at sawmill, chipped at yard

Economic considerations aside, all these methods are practicable with the bark peeling and chipping equipment now available. There is also a chance of expanding the list if it becomes feasible to remove bark after chipping as well as before. Experiments with hammermills, air and liquid flotation, and centrifugal separators offer promise, but, to date, results with southern pine have not been fully satisfactory.

ESTIMATING THE EFFICIENCY OF SALVAGE METHODS

If all the ten salvage methods for which suitable equipment is now available were in use today, their relative efficiencies could be measured in terms of the cost of chips delivered to pulpmills. Unfortunately, only a few of them are in use, and their period of operation has been too brief to provide much data. Lacking sufficient actual operations to study, we have attempted to predict the prospective efficiencies by evaluating the various factors that would determine chip cost.

Of the factors affecting efficiency, some, such as residue output rates, concentrations, and selling prices, were investigated by area surveys.[1] Others, such as dimensions of slabs and edgings, their wood content in terms of volume and weight, and the proportion of bark, were sampled at sawmills.[2] Data on machine prices, performance characteristics, production rates, labor and power requirements, maintenance costs, and the like were obtained from machine manufacturers and users. Labor costs other than for machine tending were measured by time studies. This left only truck and rail transportation costs, which could be derived largely from published material.

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[1] Todd, A.S., Jr. Sawmill and logging residues in the South Carolina Piedmont. Southeast. Forest Expt. Sta. Paper 31, 32 pp., illus. 1953.

[2] Todd, A.S., Jr. and Anderson, W.C. Size, volume, and weight of pine slabs and edgings in the South Carolina Piedmont. Southeast. Forest Expt. Sta. Paper 49, 21 pp., illus. 1955.

For convenience in costing, all the salvage methods were reduced to their common operational components, namely: (1) debarking, (2) chipping, (3) handling, and (4) truck and rail transportation (including loading and unloading). Cost estimates were prepared for each of these components. The component costs were then combined with residue price information so that the unit cost of bark-free chips at various levels of output could be calculated under each method of salvage. From the results, it was possible to determine the lowest cost output for each method and, conversely, the lowest cost method for any output.

VOLUME-WEIGHT CONVERSIONS

Most of the costs in the body of this report are per 128 cubic-foot cord of bark-free slabs or per "unit" of unscreened chips. On the average, a bark-free cord of freshly-cut pine slabs in the Piedmont will contain 79 cubic feet of wood weighing 5,000 pounds. A unit of unscreened chips is defined as the quantity produced from a cord of bark-free slabs. Thus, it too weighs 5,000 pounds.

Consequently, to convert any cost per bark-free cord or per unit of chips to an equivalent cost per thousand pounds, divide it by 5. To convert volume in cords or units to thousands of pounds, multiply by 5.

COMPONENT COSTS

The per-cord costs in the following pages are approximations of the actual costs that might be experienced in procuring, transporting, and processing various quantities of slabs and edgings from the small sawmills of a typical Piedmont area. The accompanying text and the appendix show how they were derived. The presentation will enable a reader to follow the development of cost estimates, judge their reasonableness, and substitute data of his own wherever he pleases in the computations.

Price of Slabs and Edgings at the Sawmill Sites

The greater part of the slabs and edgings produced at small pine sawmills are neither salable nor needed for fuel. In some cases, the unwanted residues are burned, but danger of the fire restricts this practice to certain locations and seasons. More commonly, the residues just accumulate.

To the landowner, the rotting piles of worthless material are an eyesore, a fire hazard, and a waste of the land they occupy. To the sawmill operator, they are a nuisance and represent an unproductive use of the labor required to build them. Landowner and sawmill operator alike might be better off if the residues were not piled at all but were given away as fast as they came from the saw.

The cost of piling is substantial. The average portable sawmill devotes about $1\frac{1}{4}$ man-hours per thousand board-feet to waste disposal. Nearly half of this time would be saved if the slabs and edgings could be loaded on trucks, trailers, or pallets rather than piled. At a typical 8,000 board-foot-a-day mill, 50 percent of one man's time would be freed for increased production. The authors estimate that as much as $8 a day might be added to the net income of the operation in this way.

For the reasons just discussed, one-half to three-quarters of the residues produced at small pine sawmills have zero or even negative value. Consequently, it seems probable that anyone wishing to procure a small quantity of rough slabs or edging strips could do so merely by hauling them away. However, in most parts of the Southeast, a procurement program of any size would involve competition with the already existing demand for fuel. A survey of a typical area in the South Carolina Piedmont reveals the extent of the fuelwood market and the current market value of residues (table 1). This area supports a predominantly rural population of 50 persons per square mile. Output of slabs and edgings is roughly 20 standard cords per square mile per year. How this output compares with that of other areas of the Southeast is shown in figure 1.

Table 1.--Proportion of sawmill residues available at various prices

Price per cord (Dollars)	Quantity
	Percent of total
(1/)	64
0.25	69
.50	73
.75	77
1.00	81
1.50	87
2.00	93
2.50	98
2.75	100

1/ No value.

The values in table 1 are for rough residues at the mill site before processing of any kind. Volumes unused or given away are considered valueless; volumes consumed by landowners and sawmill hands have been assigned values based on the prices reported for actual sales of fuelwood. The quantity percents are cumulative, so each represents the quantity presumably available at the stated price or less.

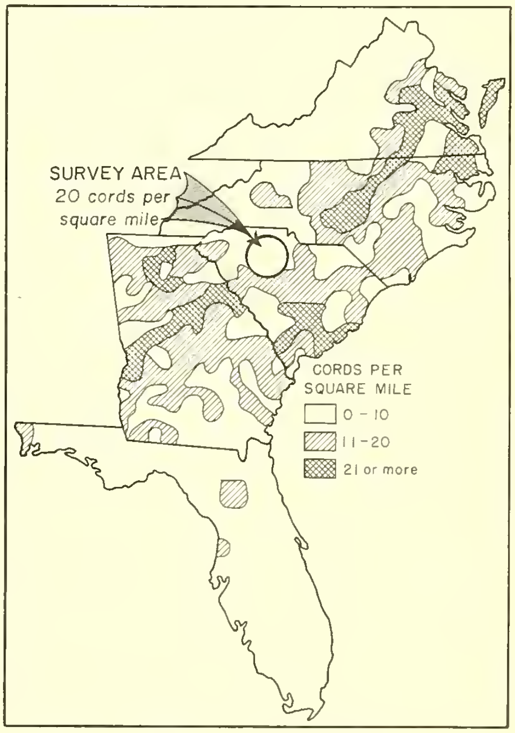


Figure 1.--Annual output of pine sawmill residues in the survey area and elsewhere in the Southeast.

Cost of Trucking Sawmill Residues

So much for the market value of slabs and edgings at the sawmills. By offering the equivalent of contract hauling charges (and thus a profit) for delivered residues, a small volume might be obtained without the necessity of owning or hiring trucks. Current trucking rates for slabs and edgings (and also for chips) are approximately as shown in table 2.

Table 2.--Contract trucking charges for sawmill residues and chips [1]

One-way distance (Miles)	Rough slabs & edgings [2]	Bark-free slabs & edgings	Chips
	Dollars per cord	Dollars per cord	Dollars per unit
5	2.20	2.60	--
10	2.80	3.30	--
15	3.40	4.00	--
20	3.90	4.60	--
25	4.40	5.20	2.50
30	4.90	5.80	3.00
40	5.50	6.50	3.80
50	6.10	7.20	4.40
60	6.50	7.70	4.80
70	6.90	8.10	5.10

[1] Based on charges for residues and green pine lumber reported by a number of southeastern firms.

[2] For cost per bark-free cord of trucking "barky" residues, multiply these values by 1.5.

The charges presented are based on the assumption that slabs will be hauled up to 30 miles by truck, averaging 3 cords per trip, and beyond 30 miles by semi-trailer, averaging 6 cords per trip. The chip charges are based on the use of semi-trailers carrying 7 "units," a unit being defined as the volume of chips produced from a cord of bark-free slabs. Included in the slab rates are an allowance for time spent hand-loading at the sawmill and dump or power unloading at destination. It is assumed that chips will be loaded by gravity or blower and unloaded by dumping or power methods.

Delivered Cost of Sawmill Residues

Combining the information of tables 1 and 2 provides estimates of the delivered cost of slabs and edgings in our typical Piedmont area (fig. 2).

The prices in table 1 and figure 2 are minimum prices. In the first place, they are based on the assumption that fuelwood buyers will pay no more than present prices for residues, so that slabs and edgings can be diverted from fuel use by slightly higher bids. However, since practically two-thirds of the residues produced are now unsalable at any price, the price-quantity relationships indicated in table 1 may not reflect the true demand for fuelwood. Secondly, it is probably erroneous to assume that all owners of residues presently unsalable would be willing to give them away. Actually, if potential buyers appeared, they would find that some owners had minimum prices below which they would refuse to sell. Thirdly, the prices would apply only so long as a surplus of residues existed.

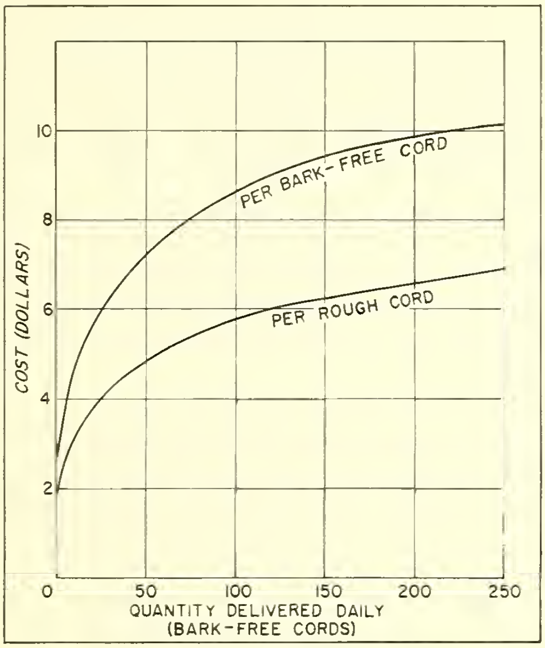


Figure 2.--Cost of barky residues, per cord, delivered to a Piedmont point.

The first of these qualifications is of little practical significance. Even in the unlikely event that fuelwood consumers refused to be outbid and other buyers were forced to draw entirely from the surplus residues not needed for fuel, the rise in delivered price would amount to less than 25 cents per cord. The second qualification, that owners of surplus residues might be unwilling to give them away, is not too important either. With no other market for their residues, owners may have to be content with a nominal price.

The third and last qualification is potentially more important. The prices in table 1 and figure 2 reflect the fact that the slabwood market currently absorbs only about one-third of the output. Superimposing a new demand on top of the existing demand for fuelwood will tend to reduce the surplus. Nevertheless, as long as untapped sources of slabs can be drawn upon by expanding the procurement territory, sellers will be powerless to force the price upward. Since anything approaching full utilization of sawmill residues is probably years away, the prices of table 1 and figure 2 will be used in this report.

Debarking Costs

At the present time, there are more than 100 log-barker installations in the South. Most of these are at the larger pine sawmills. As a result, the advantages of whole-log debarking are fairly well established. From a conservation standpoint, the most important feature of a debarked log is that practically every bit of solid waste produced in sawing it is easily salvable for chipping. In addition, a sawyer can do a better job on a clean log, with the result that the lumber out-turn is greater both in total and in proportion of upper grades. Supplementary benefits are a marked saving in saw maintenance, less "down time" while saws are being filed or changed, and a cleaner sawmill. For these reasons, the installation of log barkers often results in 10 to 15 percent increases in lumber production rates.

Small sawmills could presumably reap the same benefits from log barking. At present, however, there is no log barker fully suited to small-mill use. Existing equipment is too large, too heavy, or too expensive.

The design of log barkers is still in a state of flux. Among the current models are machines using chain flails, cutter-heads, hydraulic pressure, and concentric rings of debarking tools. They employ a variety of feed works, and vary widely in their capacities, power requirements, and the number of men required to operate them. Consequently, it is impossible to generalize on the subject of log debarking costs. About all that can be concluded is that the mean daily cost (including the operators' wages but excluding power) of owning and operating a log barker is about $44 when it is operated at capacity. Of course, individual models may vary considerably from this figure.

A barker at a typical 8,000 board-feet-per-day sawmill would operate at only a fraction of capacity. Consequently, it could probably operate with one less man than would be needed at full capacity. Making this adjustment and adding in the cost of a suitable gasoline power unit gives an estimated daily cost of $39.

If we assume that the production of an 8,000 board-foot sawmill would be increased 10 percent by the installation of a log barker, the resulting output would be 8,800 board-feet of lumber and approximately 5.3 cords (bark-free basis) of slabs and edgings per day. Charging $39 of debarking cost to 5.3 cords of chippable material results in a mean cost of $7. 35 per cord. Under present conditions, the extra 800 board-feet of lumber and reduced saw maintenance would add an amount to lumber operating profit equivalent to about $3.10 per cord. Deducting this from $7. 35 leaves a balance of $4. 25 per cord directly chargeable to the bark-free slabs and edgings.

The alternative to whole log debarking is to debark the slabs and edgings, and there are a number of machines for this purpose. They range from small, hand-fed, cutter-head models to hydraulic models with automatic feed, capable of debarking 200 or more cords per day. As might be expected, the highest-priced machines require the least manpower per unit of output. When both machine cost and operator's wages are taken into account, slab barkers show an apparent trend toward greater efficiency with increasing size (fig. 3). As given, the costs include operators' wages but no allowance for a power source. Costs of owning and operating gasoline and diesel power units and electric motors are presented elsewhere.

It will be noted that there is a break in the per-cord cost curve for slab barkers. This break results from the fact that no commercial machines are yet available in the 20 to 60 cords-per-day capacity range. All the mechanical models, as represented by the sharply declining and curved first segment of the chart, fall below this range; all the hydraulics, as represented by the smoothly curved last segment, are above it. Cost calculations which include the cost of power indicate that for outputs of 20 to 55 cords per day it is cheaper to add mechanical units than to employ a hydraulic barker at partial capacity. This use of multiple units is represented by the horizontal, straight-line portion of the curve in figure 3.

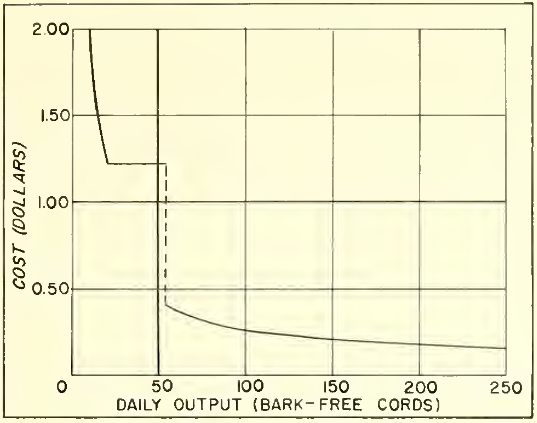


Figure 3.--Cost per bark-free cord of operating slab barker.

In discussing log barkers, we mentioned that the installation of one at a sawmill could be expected to boost lumber production 10 percent or more and reduce the cost of saw maintenance. Slab barkers do not produce collateral benefits of this kind. Consequently, the entire cost of owning and operating them is a charge against the bark-free slabs and edgings produced.

Since slab barkers contribute nothing to the lumber operation, there is no necessity of locating them at sawmills. Of course, transportation savings will result from eliminating the bark weight at the source. On the other hand, debarking at a pulpmill or slab concentration point permits closer quality control and economies of large-scale operation.

Hand debarking, either of logs or slabs, will not be considered here. It is too wasteful of manpower. Also, buyers of pulpwood, poles, and other products which were once peeled by hand in the woods report that men willing to do this type of work are almost impossible to find.

Chipper Costs

Slab chippers sell for a wide range of prices. The costs presented in this report (fig. 4) are for a line of 6-knife, overhead-discharge chippers manufactured and extensively used as waste-wood chippers in the South. These costs are for the chipper alone; power and labor are additional.

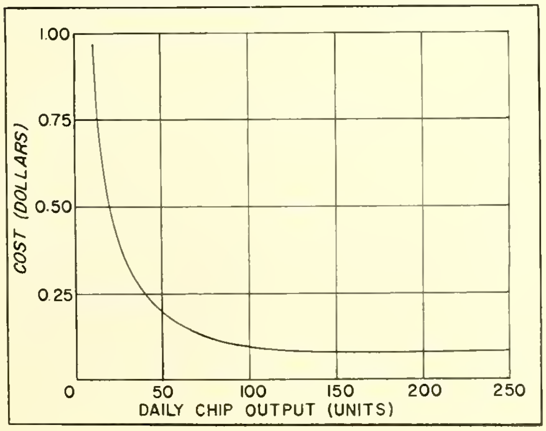


Figure 4.--Cost of operating slab chipper, per unit of unscreened chips.

Like slab barkers, chippers could be installed at sawmills, at concentration points, or at the pulpmill. However, even the smallest chippers could process the full slab output of most small sawmills in an hour per day. Consequently, if chipping is to be done at the mill sites, it might be more efficient to employ portable equipment that could be moved periodically to accumulation of slabs.

Materials Handling Costs

If debarking or debarking and chipping are performed at small sawmills, the volume of material to be handled is not great enough to justify powered conveyors. Ordinary roll tables such as are used to remove lumber from the saw will suffice for slabs, and chippers can be fitted with vanes to blow chips into trucks or other vehicles. However, if the processing is to be done in quantity at a central location, mechanized handling is probably a must. The equipment for this purpose might consist of a crane or fork-lift truck to unload the incoming slabs, belt or chain conveyors to move slabs and bark, and either belt or pneumatic conveyors for the chips.

For the purposes of this report, three types of slab processing plants can be considered. The first is merely a debarking plant that receives barky slabs and turns them out bark-free. The second receives slabs already debarked and reduces them to chips. The third is an integrated plant that both debarks and chips. The conveyor needs of the first type would be satisfied by two short, flat belts, one leading to the slab barker and one from the barker to a truck or railroad car, plus a drag chain to convey bark and scraps to the refuse burner. The needs of a chipping plant would be even simpler, since chipping produces very little refuse. However, a chipping plant of any size would ordinarily require some sort of chip storage bin or silo and, if the output is to be shipped by rail, pneumatic loading or use of a car shaker would insure greater compaction and weight per car than plain gravity loading.

The conveyor needs of an integrated debarking and chipping plant are essentially a combination of those just described for the nonintegrated operations. In addition, every plant would require facilities for unloading slabs from trucks. In some cases, a simple hand hoist might be sufficient. At larger capacity plants, the need for maintaining a yard inventory of residues would make a mobile crane or fork-lift truck essential. Figure 5 shows the estimated per-cord cost (excluding power and labor) of handling materials at each of the types of plants mentioned.

Power Costs

All the machine costs discussed above, except those for log barkers, are exclusive of power. The average horsepower requirements of various types and sizes of machines used at slab processing installations are shown in the appendix on pages 30 and 31. Page 33 shows the cost of owning and operating electric motors. The kilowatt-hour rates for electricity (page 34) are those currently charged by a North Carolina power company. Translated

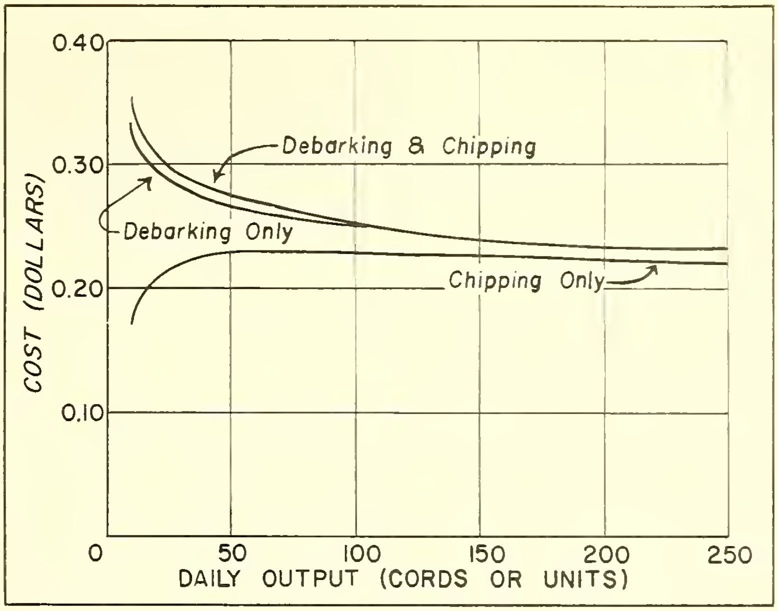


Figure 5.--Cost per bark-free cord (or unit of unscreened chips) of operating conveyors, etc. at three types of processing installations.

to a per-cord basis, the costs of providing electric power for debarking, chipping, and integrated plants are shown in figure 6. For the sake of simplicity, we have omitted a similar chart for gasoline and diesel power, but the necessary cost data will be found on page 35.

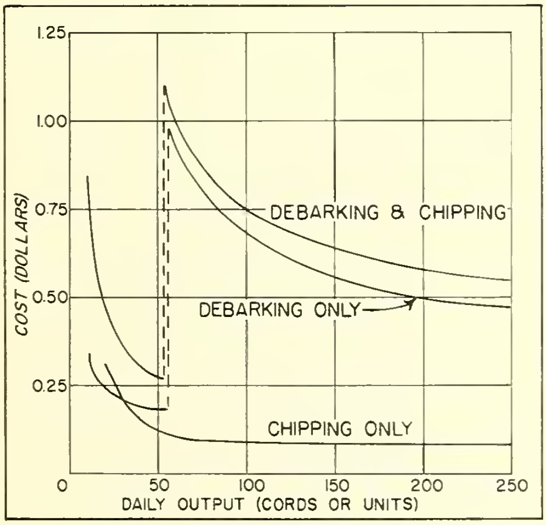


Figure 6.--Cost per bark-free cord (or unit of unscreened chips) of electricity to power three types of processing installations.

Labor Costs

Readers of the preceding pages may have wondered why debarking costs included operators' wages, while wages were left out of all other processing costs. The explanation lies in the nature of the machines involved. Chippers and conveyors are automatic machines. When properly combined, they require human attention only for maintenance and in the event of jamming. A slab barker, on the other hand, commands the full-time services of one or more men as long as it is operating. Furthermore, the degree of automation built into a barker does not necessarily determine its production rate. In the same capacity class one can find high-priced semi-automatic machines and lower-priced machines with high labor requirements. Consequently, cost can be related to capacity only when the operators' wages are included.

The amount of manpower allowed for in computing barker costs was based on manufacturers' recommendations and users' experience. Unfortunately, it is not possible to estimate the manpower requirements of complete slab processing plants with the same assurance. Therefore, figure 7 is presented with no claims as to its accuracy. However, the values appear to be in line with crew organizations observed at several barker-chipper operations.

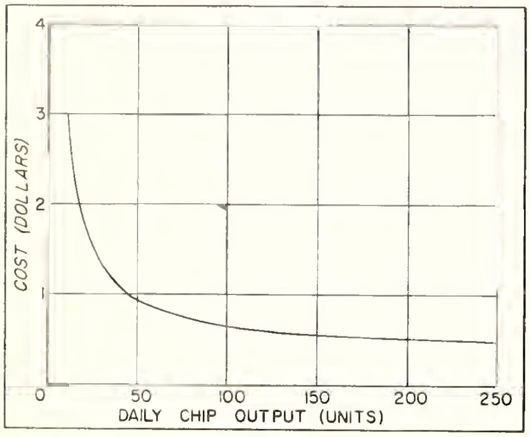


Figure 7.--Cost of labor per unit of unscreened chips, to operate a processing installation (exclusive of barker operators).

Rail Freight

The costs of trucking residues and chips from sawmills were discussed in an earlier section and summarized in table 2. In most cases, truck transportation is the only practicable method of moving the material from a small sawmill to its first destination. Nevertheless, rail freight is likely to be cheaper for the longer distances, and particularly for reshipments from concentration points.

As yet, there are no rail rate schedules for sawmill residues or chips in this part of the country. However, local chip rates have been established for point-to-point shipments in many places. These rates were individually determined and vary somewhat for a given mileage, but the values in table 3 are about average. The slab and edging rates in the table are based on the assumption that when a schedule is established, it will follow the existing schedule for pulpwood, as was the case in the West.

COSTS OF COMPLETE SALVAGE METHODS

There are 10 salvage methods to be considered (see page 3). A pulpmill requiring only a limited volume of residues from small sawmills would presumably select one or more of the first five methods. The residues, whether rough or bark-free or in the form of chips, would be trucked directly to the pulpmill from sawmills in the vicinity. However, with increasing residue requirements and the need to draw from more and more distant sawmills, a point will be reached where one of the second five methods will be more economical. Similarly, if the requirements continue to increase after a concentration yard has been established, it will eventually become more economical to establish a second yard than to extend the drawing territory of the first any farther. Of course, if the debarking and chipping are to be done either at the sawmill or at the pulpmill (Method 6), yards are not an absolute necessity. Residues can be transferred from trucks to railroad cars at sidings near the points of origin.

Costs of Methods Involving Direct Shipment

Where rough slabs and edgings are to be delivered to a pulpmill (Method 1), their cost upon arrival consists of the purchase price of the residues and the trucking charge. The delivered cost of rough residues both per rough cord and per bark-free cord was estimated in figure 2. The costs per bark-free cord from figure 2 form the bottom curve of figure 8.

The curves in figure 8 show how the cost components can be combined to arrive at the average cost curve for a complete salvage method, in this case Method 1. They also indicate the shape of the problem posed by the economics of residue salvage at small sawmills.

Table 3.--Rail freight charges for sawmill residues and chips [1]

Distance (Miles)	Rough slabs and edgings [2]	Bark-free slabs and edgings	Chips
	- - - Dollars per cord	- -	Dollars per unit
50	2.10	2.50	2.60
60	2.30	2.70	2.80
70	2.40	2.80	2.90
80	2.50	2.90	3.00
90	2.60	3.10	3.20
100	2.80	3.20	3.30
120	3.00	3.50	3.60
140	3.30	3.80	3.90
160	3.50	4.10	4.20
180	3.80	4.40	4.50
200	4.00	4.70	4.80
220	4.30	5.00	5.20
240	4.50	5.30	5.50
260	4.80	5.60	5.80
280	5.00	5.90	6.10
300	5.30	6.20	6.40

[1] Includes 3 percent Federal tax.

[2] In this case freight is being paid on bark. That is to say, the charge for transporting wood and bark has to be borne by wood alone. To find this cost per bark-free cord for shipping "barky" residues, multiply values given in the column by 1.5.

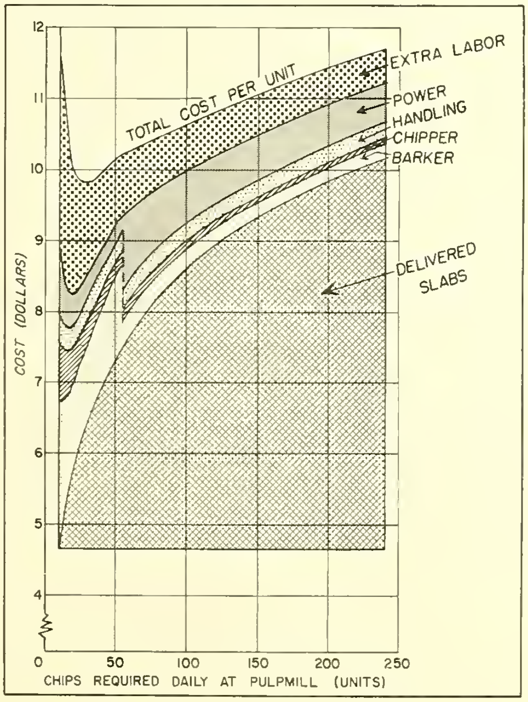


Figure 8.--Cost per unit of unscreened chips when rough slabs and edgings are trucked directly from sawmill to pulpmill and processed at the pulpmill.

For instance, the curves show that average processing costs are high when the volume of material handled is low, and that they decline rapidly at first as the volume increases, then at a less rapid rate, finally stabilizing at a near-constant figure. The delivered cost of slabs, on the other hand, is low at the smallest volume and rises rapidly (but at a declining rate) as the volume increases. Thus, volume has opposite effects on the cost of the residues and on the cost of processing them. However, the two are never compensating; processing is the more critical item at volumes up to 25 units per day, and slab cost at volumes above that.

In the discussion of slab debarking, attention was called to the break in the average cost curve at the point where hydraulic equipment replaces mechanical machines. This break shows up in figure 8. However, note that the addition of power results in a fairly smooth curve for total per-cord debarking cost.

As one alternative to delivering rough slabs, a log or slab barker could be installed at the sawmill, and bark-free slabs could be delivered to the pulpmill (Methods 2 and 3, respectively). Another alternative is to install a chipper as well as debarking machinery at the sawmill, and deliver chips to the pulpmill (Methods 4 and 5).

Figure 9A shows the cost of chips produced by each of these five methods. Curve 1 corresponds to the top or total average cost curve of figure 8. The other curves were obtained in the same fashion by summing the appropriate cost components. The costs of Methods 2 through 5, which require processing of residues at sawmills, are based on a typical small-mill capacity of 8,000 board-feet per day. Costs of processing would be less at larger sawmills and somewhat more at smaller ones.

Method 1, which involves the delivery of rough residues and centralizes debarking and chipping at the pulpmill, is the cheapest. It can produce chips for 50 to 75 cents less per unit than any other method, except when the quantity handled is very small. Methods 2 and 4, which involve log debarking at sawmills, are next, while Methods 3 and 5, which call for slab debarking at sawmills are the most expensive.

In practice, the cost advantage of Method 1 over the others would usually be greater than shown, because the costs shown here for Methods 2 through 5 include no margin for profit and risk on the debarking or chipping operations. Therefore, these costs actually apply only to the specialized case of a pulpmill maintaining and operating barkers and chippers at sawmills.

Since the most economical method is the one that avoids any processing at sawmills, it may seem paradoxical that the next best method is one that requires all processing to be done at the sawmills. Apparently the explanation is that chipping is an inexpensive operation, while the subsequent cost of handling and transporting chips is much smaller than for slabwood.

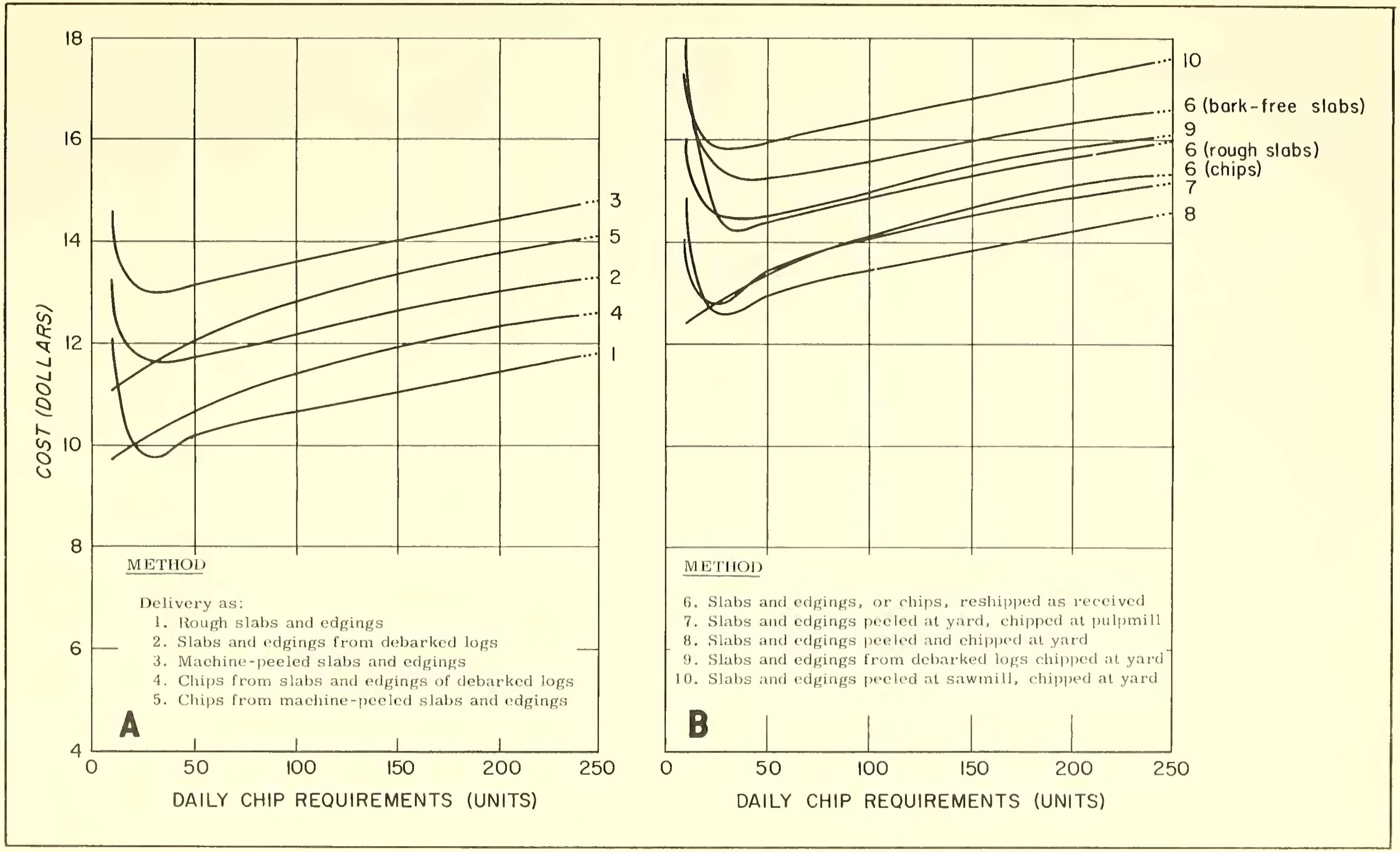


Figure 9.--Cost of unscreened chips per unit at pulpmill by ten salvage methods. A, When material is trucked from sawmill directly to pulpmill. B, When material is trucked from sawmill to concentration yard and reshipped by rail to pulpmill.

In discussing the components of the Method 1 cost (fig. 8), it was noted that slab cost increased with volume, while processing cost decreased. To a lesser extent this is also true of Methods 2 and 3. The result is that each of these methods attains maximum efficiency at some level of production. For Method 1, average chip cost is minimized when production is 30 units daily. It is minimized for Methods 2 and 3 at a point between 30 and 40 units.

Methods 4 and 5 are different in this respect. Average cost increases with quantity throughout the range of values calculated. The reason is that all the processing of residues under these methods is performed at sawmills of relatively fixed capacity. For all practical purposes, the volume of chips procured by a pulpmill can be changed only by varying the number of sawmills from which chips are obtained. The output per sawmill and, therefore, the processing cost do not vary. Thus, the constantly rising cost curves for Methods 4 and 5 are a reflection of the need to haul from more and more distant sawmills and to pay more for slabs from sawmills nearby as chip requirements increase.

Costs of Methods Involving Rail Shipment from Concentration Points

Few small sawmills are located on railroad sidings. In the Southeast, most small mills are portables that operate in the woods. For this reason, the bulk of the residues would have to be moved to their first destination by truck. The size and weight of these trucks would be limited by the need to negotiate crude woods roads and to maneuver in cramped space. Loaded with heavy, low-value wood residues, their economic hauling radius would consequently be rather short. Comparison of tables 2 and 3 will show that as the procurement territory of a pulpmill expands, it eventually becomes cheaper to transfer loads from trucks to railroad cars than to transport them all the way by truck.

The transfer of slabwood from truck to car could be performed at any nearby siding. If the material were bundled and a hoist available, the loads could be transferred to gondolas or flatcars at reasonable expense. However, hand reloading would mean assigning two or more men to the truck and probably could not be accomplished for much less than $2 per cord. Chip reloading would, of course, require specialized equipment. Another objection to decentralized loading is the bother and uncertainty of arranging for the spotting of cars at the right places and times. Some of these difficulties can be avoided by establishing rail concentration yards.

In its simplest form, a concentration yard might merely provide power loading machinery and reship slabs and chips in the same form as they were received. On the other hand, there is an opportunity to process slabs as well as load, thereby reducing the cost of the loading or the rail freight or both.

Figure 9 also shows the cost at destination of chips produced by each of five salvage methods involving concentration yards (Methods 6 through 10). Method 6, yard reshipment in the same form as received, is represented by three curves corresponding to the three forms (rough slabs, bark-free slabs, and chips) in which the residues might be received. For the sake of comparability, all seven cost curves in figure 9B are based on a 60-mile rail haul from yard to pulpmill. The costs do not include any provision for general administration, real estate taxes, or depreciation of buildings and other improvements.

Method 8, calling for debarking and chipping at the yard, apparently costs least at all but the smallest volumes of output. Next in order of economy are Methods 7 (debarking at yard, chipping at pulpmill) and 6 (all processing at the sawmill). The high-cost methods here are those involving slab debarking at sawmills, just as they were among the direct-shipment methods. But, here again, it appears that if any processing is to be done at the sawmills, it should all be done there. Even more important, yard processing results in lower-cost chips than processing at destination (pulpmill).

The High Cost of Processing at Sawmills

The finding that sawmill processing makes for expensive chips is perhaps worthy of further comment. Since rough slabs are one-third bark, and bark has no present value except for fuel, it would seem that bark should be removed as near the source as possible, i.e., at the sawmill. Since chipping permits cheaper handling of residues, it appears that chipping should also take place as near the source as possible. Yet, the cost curves of figure 9 indicate that more economical chips will result from deferring the debarking and chipping until the residues reach their first destination.

The explanation for the high cost of sawmill processing has been touched on before. Chief among the difficulties is the lack of efficient barkers for mills in the 8,000 board-feet-per-day class. Log barkers now in production are too large and too expensive, and slab barkers are either large and expensive or require too much labor. Even the smallest chippers possess considerable excess capacity for mills of this size, but their use would still be feasible if the bark could be removed economically.

In this connection, whole-log barkers show up better costwise than slab barkers for sawmill installation. The explanation, of course, is that a substantial portion of the cost of debarking logs is covered by the increased lumber production possible from peeled logs. At sawmills larger than those considered here, the added lumber income may be sufficient to bear the entire cost of barker operation.

At the present stage of machine development, the lowest-cost chips that can be produced from small-sawmill residues would be those from slab barker and chipper installations at pulpmills (Method 1). These central installations could be supplemented as needed by rail yards which would also debark and chip rough residues delivered to them (Method 8). Any other procurement system would result in higher costs.

In planning procurement by the methods just outlined, perhaps the most important decisions are those regarding the lowest cost combination of a central installation and tributary yards. Up to a point, the central installation is the most economical source of chips. However, as chip requirements expand, it becomes necessary to truck slabs from greater distances and to outbid fuel buyers for an ever larger share of the material closer in. In the early stages, the increasing cost of delivered residues is more than compensated by the greater efficiency of large-scale debarking and chipping operations. Reference to Curve 1 of figure 9 indicates that the net effect is a declining cost per unit of chips until requirements reach 30 units a day. The average cost of $9.80 per unit at 30 units is the lowest cost at which it is presently possible to produce chips in our representative Piedmont area (fig. 1). Therefore, until requirements exceed 30 units, there is no economic incentive to establish supplementary rail yards.

It may be recalled that the sawmills of our Piedmont study area produce roughly 20 cords of residues per square mile per year. What would the minimum cost points be in areas with greater or lesser concentrations of residues? It may also be recalled that nearly two-thirds of the residues in the study area have no current market value and that the top price of slabs for fuel is $2.75. What would the minimum cost points be in areas of higher and lower prices? The answer is that, for all practical purposes, the minimum cost point can be considered to be fixed for each salvage method and independent of both residue concentration and residue price.

Determining the optimum (minimum cost) combination of central and rail yards involves two decisions. The first is, when should supplementary yards be established? How large should the central yard be allowed to grow before a rail yard is put in? Then, how large should these two yards become before a second, more distant, rail yard is justified?

Once the need for a supplementary yard or yards has been demonstrated, a second decision is necessary. How should a given volume of chip production be apportioned to minimize the per-unit cost? In other words, how large should each of the yards be?

The question when to add yards and what size to make them can be answered by analyzing the costs, as follows:

When the quantity of chips processed at a central yard or rail yard is increased, each succeeding unit of chips will cost more than the one preceding it. At any level of output, say 50 units per yard, the cost of chips from a rail yard will exceed the cost of chips from the central yard by the amount of rail freight, assuming residue concentrations and prices to be uniform. However, as central yard output expands and becomes more expensive, a point will be reached where the cost of any further output will be greater than the cost, including freight, of obtaining it from a small supplementary yard. To be specific, this point is reached when the cost of the last unit of central-yard chips (marginal cost) equals the average cost of chips from some size of rail yard.

So much for the question of additional yards. How should the total volume of desired output be apportioned to yards? This can be determined by equating marginal costs. From the discussion of the preceding paragraph, it follows that for any level of output at the central yard there is a lower output at the rail yard of such a magnitude that the cost of the last unit, including freight, equals the cost of the last unit produced at the central yard. The outputs at central and rail yard which bring the costs of the last units (marginal costs) into balance represent the minimum cost division of that total quantity of output between yards. Any other allocation of the same total output would result in higher total cost.

What has been said here with regard to a single rail yard of course applies to any number of equidistant yards. If a marginal analysis indicated that a 35-unit rail yard should be established, for example, this would be justification for a ring of as many 35-unit yards as the layout of railways permitted.

Once a yard or ring of yards has been established, the same procedure can be employed in making decisions as to the establishment of more distant yards or rings of yards. In most cases, this expansion would not need to proceed very far, because the number of potential yard sites ordinarily increases rapidly with distance from the pulpmill.

As a practical demonstration of the methods just outlined for allocating chip production to yards, let us return to our typical Piedmont area. For this area, a 30-unit-per-day yard was found to be the most efficient. Consequently, rail yards cannot be justified until the output of the central yard reaches 30 units. Similarly, once a rail yard has been established, its output should reach 30 units before the installation of more distant rail yards is considered.

One more stipulation is needed--the radial distance from pulpmill to the first rail yard or yards, the distance from first rail yard to second rail yard, etc. Rail freight will be minimized when the perimeters of successive yard drawing territories touch, so this situation will be assumed. It will also be assumed that, since the perimeters of their territories touch, the rail distance between yards is approximately equal to the sum of the radii of the two territories.

Table 4 shows the optimum allocation of various volumes of chip output to yards under the conditions just outlined. Apparently, operations should be restricted to a central yard until output reached 165 units of chips. At that point, a rail yard of 27 units capacity would be justified. Similarly, when output at a rail yard reached 35 units, a second, more-distant rail yard of 27 units capacity would be in order.

Table 4.--Lowest cost allocation of chip production to yards in a Piedmont area
(In units)

Total daily requirements	Yard capacities			
	Central yard	First rail yard [1]	Second rail yard [1]	Third rail yard [1]
50	50	--	--	--
100	100	--	--	--
150	150	--	--	--
192	165	27	--	--
200	170	30	--	--
277	215	35	27	--
300	230	40	30	--
374	262	50	35	27
400	275	55	40	30

[1] Values apply also to each yard of a ring of equidistant yards.

The table column titled "Total daily requirements" contains minimum figures in the sense that these volumes would be produced if it were possible to establish only one rail yard at each distance from the pulpmill. However, pulpmills are located with an eye to easy rail connections. In practice, therefore, two or more rail yards can usually be established at each distance. Naturally, the more compact the procurement area for a given volume of daily chip requirements, the greater the economy of operation. One or two rings of rail yards close in are always preferable costwise to a string of individual yards stretching out into the distance.

As stated earlier, the least-cost capacity of a yard is independent of residue concentration or price. The same is approximately true of the least-cost allocation of output among yards. Therefore, the allocations of table 4 apply to any residue concentration or price, provided the concentration and price are the same for all yard locations. Individual calculations are necessary for situations in which the residue concentration or price varies from one yard to another.

APPENDIX

PREPARATION OF COST ESTIMATES

Most of the average cost curves presented in the text were derived from total daily cost curves. The total curves were constructed by calculating costs for particular outputs and then fitting curves to these points. The curves and the calculations on which they were based are shown in this appendix.

In some instances, the available information did not extend over the full span of outputs we wished to analyzed. This made it necessary to project some of the curves considerably beyond the range of the data. In every such case, the portion of the curve that is extrapolated is shown by a dashed line.

The original data are presented here to enable readers to appraise the costs used and the bases for their calculation. Those who have experience data of their own can calculate costs on the same basis and include them to strengthen a curve, or they can substitute them for all or some of the data presented. Others may wish to modify the calculations by using different depreciation periods or investment rates.

All investments and costs were calculated on a uniform basis so that resulting cost components could be combined. In calculating investment in equipment, manufacturers' list prices were used. Even though some dealers absorb freight, a freight allowance was added to each list price on the basis of a 500-mile shipment for machines manufactured within the South and a 1,000-mile shipment for those produced in other regions. Rates supplied by a railroad traffic agent per 100 pounds for less-than-carload lots were $2.53 for 500 miles and $3.78 for 1,000 miles. No sales taxes were added. This is consistent with the practice in states like North Carolina, which do not tax manufacturers' purchases, but is inconsistent with others such as Georgia, which tax all sales. Installation costs were added, where appropriate, to get total investments.

Total daily cost for a piece of equipment is the sum of interest on average investment, amortization of investment, ad valorem taxes, fire and extended coverage insurance, and maintenance cost. An interest rate of 6 percent per annum was charged on the average investment, which was determined from the formula I(N+1)/2N, where I is total investment and N is the estimated number of years the machine will be owned. No allowance was made for trade-ins or salvage; the total investment was depreciated by the straight-line method over the life of the machine. In calculating property taxes, assessed value was taken as 50 percent of full value less depreciation (i.e., average assessed value was one-half average investment), and the tax rate applied was $1.50 per $100 of assessed value. The premium for fire insurance and extended coverage was calculated on the basis of insured value equaling 80 percent of original value and a rate of $3.15 per $1,000 of insured value. These annual costs were reduced to a daily basis by assuming 225 eight-hour working days per year. Most of the assumptions made in calculating investment and cost tend to make the total daily cost estimates conservative (high).

Daily output is expressed in bark-free cords of slabs and edgings (79 cubic feet of solid wood). One and one-half rough cords are required to yield one bark-free cord of slabs and edgings. Thus, an output of 0.9 rough cords of slabs and edgings per thousand board-feet of lumber outturn at small sawmills will yield 0.6 bark-free cords.

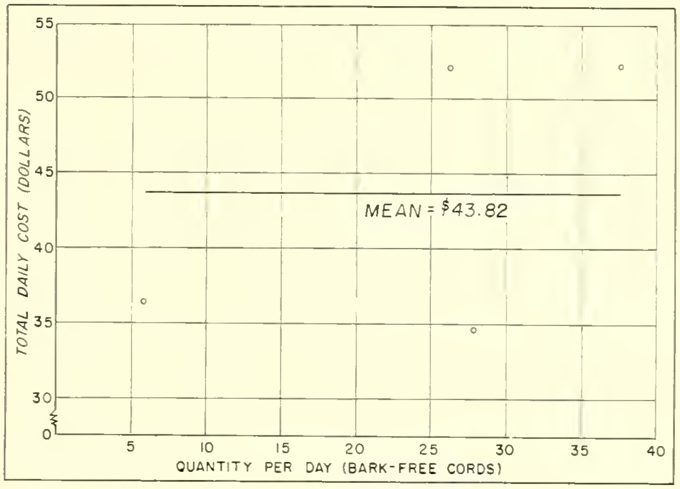
The machines used to convert rough slabs into clean chips consist of barkers, chippers, and conveyors to move material to and from them. The machine rates or operating capacities employed are approximately 75 percent of theoretical capacity. The total daily cost of operating machines does not include power, since in the case of electricity this cost varies with total installed horsepower as well as with individual machine requirements. Horsepower requirements by output for each type of machine are discussed in a later section and power costs by horsepower are presented separately.

Labor is included in the total daily cost of barkers. Other equipment costs do not include labor. The cost of additional labor for these other machines is also presented separately.

MACHINE COSTS--LOG BARKERS

Daily log-barking costs were calculated for three mechanical log barkers and one mechanical pulpwood barker which the manufacturer claimed could be modified to debark logs. Price and cost data for these barkers were obtained from published data in one case, from the manufacturer for another, and from users for the remaining two. All barkers were depreciated over 5 years, which was the period favored by users. Maintenance costs were those expected by manufacturers or experienced by users. The cost of added labor at sawmills where barkers had been installed is included in the daily cost. For three of the barkers, an additional semiskilled ($1.25-per-hour) and an unskilled ($1-per-hour) worker would be required. For the fourth barker, which feeds automatically, only one semiskilled man would be needed. The total daily costs of these four barkers plotted over residue output showed no discernible trend. Therefore, daily cost at any level of output was taken to be the average daily cost ($43.82) of these four barkers.

Daily cost of owning and operating log barkers (including labor but excluding power), by capacity



	Capacity (bark-free cords per day)			
	5.8	26.2	27.8	37.4
	Dollars			
Investment				
List price	3,000	24,000	17,000	15,000
Plus freight	90	305	85	305
Plus installation cost	500	3,000	3,000	3,000
Less knives or chains	40	40	([1])	40
Total investment	3,550	27,265	20,085	18,265
Time charges				
Machine				
Interest at 6 percent on average investment	.57	4.36	3.21	2.92
Amortization of investment in 5 years	3.16	24.24	17.85	16.24
Ad valorem taxes	.07	.54	.40	.36
Fire and extended coverage insurance	.04	.31	.22	.20
Maintenance	13.20	3.29	1.78	13.20
Total machine cost	17.04	32.74	23.46	32.92
Labor				
Wages	18.00	18.00	10.00	18.00
Payments for Social Security, state unemployment compensation, and workmen's insurance	1.44	1.44	.80	1.44
Total labor cost	19.44	19.44	10.80	19.44
Total cost (for one 8-hour day)	36.48	52.18	34.26	52.36

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[1] No chains or knives.

There are two general types of slab barkers--mechanical and hydraulic. Comparisons of operating costs (including power) indicate that mechanical barkers have the lowest average costs at outputs of less than 55 bark-free cords per day, while hydraulic barkers are more economical at larger outputs. This breakeven point was calculated from the data and assumptions presented here, and is not intended to apply to specific machines.

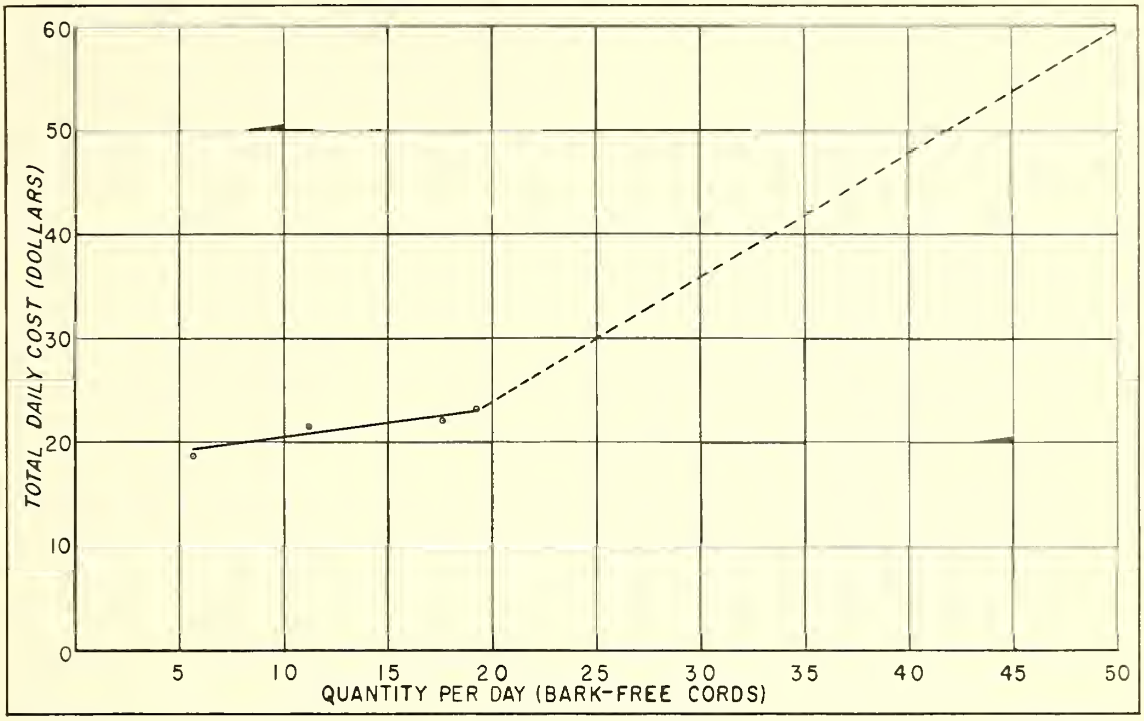
Total daily costs were calculated for four mechanical slab barkers which removed bark by chain flail, hammer, rosser head, or disc-mounted knife. Price and cost data came from published material and interviews with manufacturers and users. The life of slab barkers was taken to be 5 years, or the same as for log barkers. This is in accord with the opinion of some manufacturers and most users. Because mechanical slab barkers are still in an early state of development, the chance of obsolescence due to rapid changes in design and construction are high.

Maintenance costs were approximated from information supplied by manufacturers and users. Labor was included by adding in wages and other payments for one or two unskilled laborers as recommended by manufacturers or users. The total daily cost values when plotted over output fell very nearly in a straight line.

The trend of the fitted line could have been projected over larger outputs. If this were done, the mechanical barkers would show lower costs than the hydraulic barkers at all outputs considered. This was known to be unrealistic, since hydraulic barkers with daily capacities as low as 40 cords are marketed. Therefore, it was decided to assume arbitrarily that at outputs beyond 19 bark-free cords per day (the largest mechanical barker for which we had data) increased outputs would be obtained only by increasing the number of units. It was on this basis that the daily cost curve for mechanical barkers was projected.

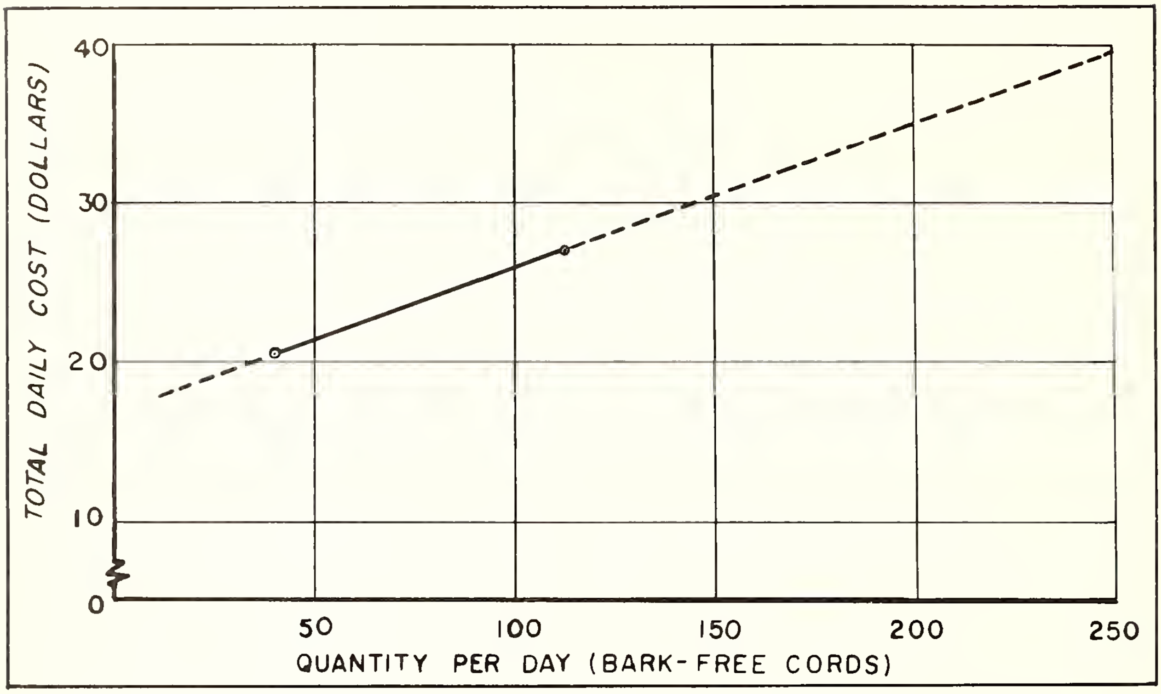
The curve for daily operating costs for hydraulic slab barkers was based on costs for two models. The data for one were obtained from an interview with the manufacturer, and for the other from published figures. Hydraulic barkers were depreciated over 10 years because these machines are subject to less vibration and have fewer wearing parts than mechanical models. Maintenance costs were based on manufacturer's estimates, because none of these machines had been operated a sufficiently long time to provide experience to date. The wages and labor payments for one unskilled operator to feed slabs and edgings were included in the cost of each machine.

Daily cost of owning and operating mechanical slab barkers (including labor but excluding power), by capacity



	Capacity (bark-free cords per day)			
	5.6	11.2	17.6	19.2
	Dollars			
Investment				
List price	1,000	9,200	8,250	3,500
Freight	25	50	100	50
Installation cost	100	100	100	100
Total investment	1,125	9,350	8,450	3,650
Time charges				
Machine				
Interest at 6 percent on average investment	.18	1.50	1.35	.58
Amortization of investment in 5 years	1.00	8.31	7.51	3.24
Ad valorem taxes	.02	.16	.14	.06
Fire and extended coverage insurance	.01	.10	.09	.04
Maintenance	.25	2.80	4.40	2.00
Total machine cost	1.46	12.87	13.49	5.92
Labor				
Wages	16.00	8.00	8.00	16.00
Payment for Social Security, state unemployment compensation, and workmen's insurance	1.28	.64	.64	1.28
Total labor cost	17.28	8.64	8.64	17.28
Total cost (for one 8-hour day)	18.74	21.51	22.13	23.20

Daily cost of owning and operating hydraulic slab barkers (including labor excluding power), by capacity

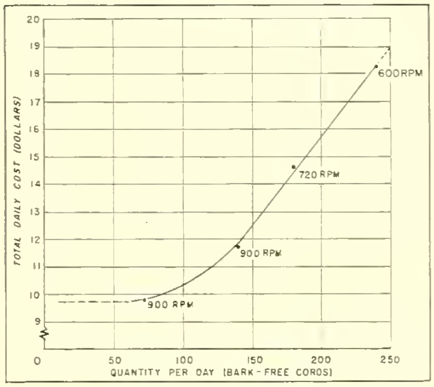


	Capacity (bark-free cords per day)	
	40.0	112.0
	Dollars	Dollars
Investment		
List price	15,512	20,000
Freight	150	200
Installation cost	300	400
Total investment	15,962	20,600
Time charges		
Machine		
Interest at 6 percent on average investment	2.34	3.03
Amortization of investment in 10 years	7.09	9.15
Ad valorem taxes	.29	.37
Fire and extended coverage insurance	.18	.23
Maintenance	2.00	5.60
Total machine cost	11.90	18.38
Labor		
Wages	8.00	8.00
Payment for Social Security, state unemployment compensation and workmen's insurance	.64	.64
Total labor cost	8.64	8.64
Total cost (for one 8-hour day)	20.54	27.02

MACHINE COSTS--CHIPPERS

The total daily cost of owning and operating chippers was calculated for 6-knife machines with disc diameters of 36, 48, 60, and 74 inches. They are of a design which provides a positive feed without feed works. Their prices were therefore somewhat lower than machines requiring this additional mechanism. Chipper investment was amortized in 10 years, the period over which most users planned to depreciate them. Maintenance costs were based on the average practices of users. Most users change and sharpen knives daily and replace them every 4 months. They turn the anvil every 3 weeks, and since it has 4 sides, replace it every 12 weeks. Chipper costs were plotted over capacity outputs, based on 12½ percent spout loading. In projecting chipper costs over outputs less than the capacity of the smallest chipper, it was assumed that costs would not be significantly reduced at these outputs.

Daily cost of owning and operating 6-knife chippers (excluding cost of labor and power), by capacity

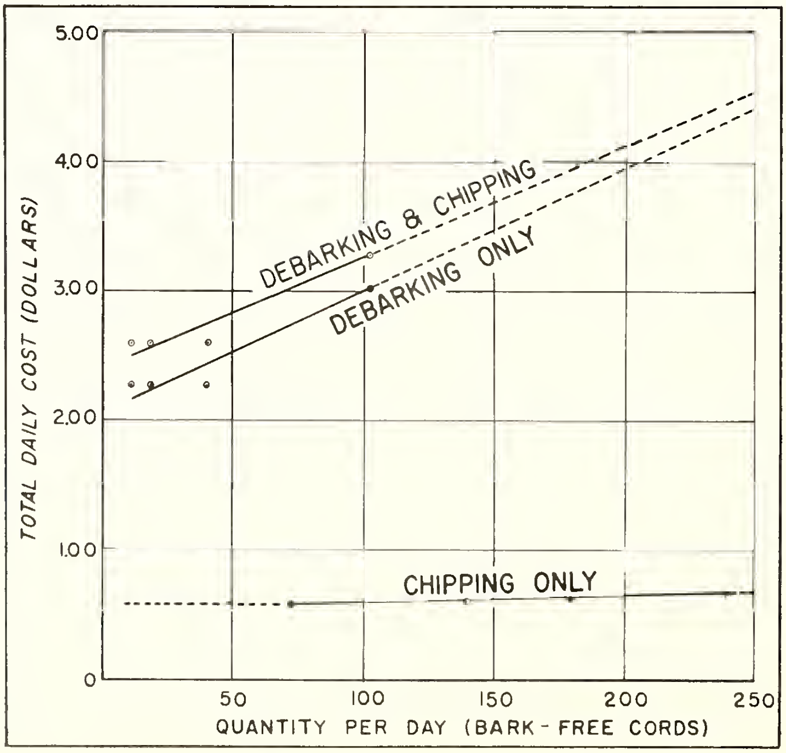


	Capacity (bark-free cords per day)			
	72	140	180	240
	Dollars			
Investment				
List price	5,260	8,015	12,180	17,480
Plus freight	80	150	255	410
Less knives and belts	200	225	245	270
Total investment	5,140	7,940	12,190	17,620
Time charges				
Interest at 6 percent on average investment	.75	1.16	1.79	2.58
Amortization of investment in 10 years	2.28	3.53	5.42	7.83
Ad valorem taxes	.10	.15	.23	.33
Fire and extended coverage insurance	.06	.09	.14	.20
Maintenance	6.55	6.80	7.05	7.35
Total cost (for one 8-hour day)	9.74	11.73	14.63	18.29

Daily costs were calculated for three conveyor systems at pulpmills or field locations. One system is for an installation processing only clean slabs into chips, another for one only debarking rough slabs, and the third is for a complete installation converting rough slabs to clean chips. A chipper installation would require merely a belt conveyor about 25 feet long conveying slabs to the chipper, and a blow pipe about 25 feet long leading to the loading point. A barker installation would require a 25-foot belt conveyor for rough slabs leading to the barker, a second 25-foot belt conveyor to move clean slabs to the loading point, and a 100-foot drag chain to carry bark from the barker to the burner. A complete installation would require a belt conveyor for rough slabs to the barker, a drag chain for bark to the burner, a belt for clean slabs between barker and chipper, and a blow pipe for chips from the chipper to the loading point.

Conveyor prices and assembly costs were obtained from the engineer for a wholesale firm selling both fabricated conveyors and parts and pieces. Conveyor systems were depreciated over 5 years, except in the case of chipper installations, where a 10-year period was used to coincide with the period used for chippers. Balanced curves were fitted to the plotted points and the trends projected. In the case of the system for chipper installations, cost was projected horizontally over lower outputs the same as for chippers.

Daily cost of owning and operating conveyor systems (excluding power) for three kinds of installations, by capacity



CHIPPER INSTALLATION

	Capacity (bark-free cords per day)							
	11.2	17.6	40	72	112	140	180	240
	Dollars							
Investment								
List price	--	--	--	763	--	813	838	888
Freight	--	--	--	25	--	25	25	25
Installation cost	--	--	--	150	--	155	160	165
Total investment	--	--	--	938	--	993	1,023	1,078
Time charges								
Interest at 6 percent on average investment	--	--	--	.14	--	.15	.15	.16
Amortization of investment in 10 years	--	--	--	.42	--	.44	.45	.48
Ad valorem taxes	--	--	--	.02	--	.02	.02	.02
Fire and extended coverage insurance	--	--	--	.01	--	.01	.01	.01
Maintenance	--	--	--	(1/)	--	(1/)	(1/)	(1/)
Total cost (for one 8-hour day)	--	--	--	.59	--	.62	.63	.67

BARKER INSTALLATION

Investment								
List price	1,751	1,751	1,751	--	2,305	--	--	--
Freight	60	60	60	--	100	--	--	--
Installation cost	290	290	290	--	390	--	--	--
Total investment	2,101	2,101	2,101	--	2,795	--	--	--
Time charges								
Interest at 6 percent on average investment	.34	.34	.34	--	.45	--	--	--
Amortization of investment in 5 years	1.87	1.87	1.87	--	2.48	--	--	--
Ad valorem taxes	.04	.04	.04	--	.06	--	--	--
Fire and extended coverage insurance	.02	.02	.02	--	.03	--	--	--
Maintenance	(1/)	(1/)	(1/)	--	(1/)	--	--	--
Total cost (for one 8-hour day)	2.27	2.27	2.27	--	3.02	--	--	--

COMBINED BARKER AND CHIPPER INSTALLATION

Investment								
List price	1,986	1,986	1,986	--	2,540	--	--	--
Freight	65	65	65	--	105	--	--	--
Installation cost	340	340	340	--	395	--	--	--
Total investment	2,391	2,391	2,391	--	3,040	--	--	--
Time charges								
Interest at 6 percent on average investment	.38	.38	.38	--	.49	--	--	--
Amortization of investment in 5 years	2.13	2.13	2.13	--	2.70	--	--	--
Ad valorem taxes	.05	.05	.05	--	.06	--	--	--
Fire and extended coverage insurance	.03	.03	.03	--	.03	--	--	--
Maintenance	(1/)	(1/)	(1/)	--	(1/)	--	--	--
Total cost (for one 8-hour day)	2.59	2.59	2.59	--	3.28	--	--	--

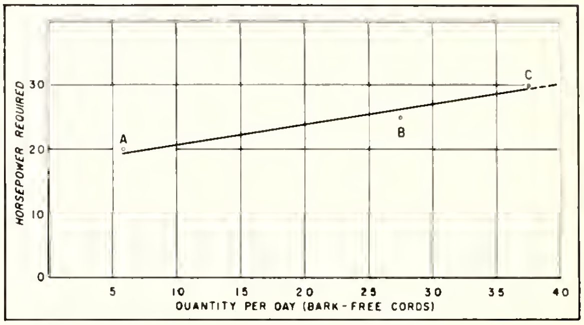
1/ Assumed no maintenance cost.

HORSEPOWER REQUIREMENTS

To relate power to machines, it was necessary to know for each type of machine the relationship between residue output and horsepower requirements. The horsepower requirements given by manufacturers and users of individual pieces of machinery were plotted over operating outputs. Straight line balanced curves were then fitted graphically to each set of plotted points. Extrapolations were necessary for mechanical log barkers and hydraulic slab barkers. The horsepower requirements for mechanical slab barkers were projected on the assumption that additional units would be needed for volumes greater than 19 cords. For chippers the same horsepower was shown for all outputs up to 72 cords per day, since the same machine could be used at all of these outputs. Conveyor horsepower requirements were calculated separately for barker installations, chipper installations, and complete debarking and chipping installations.

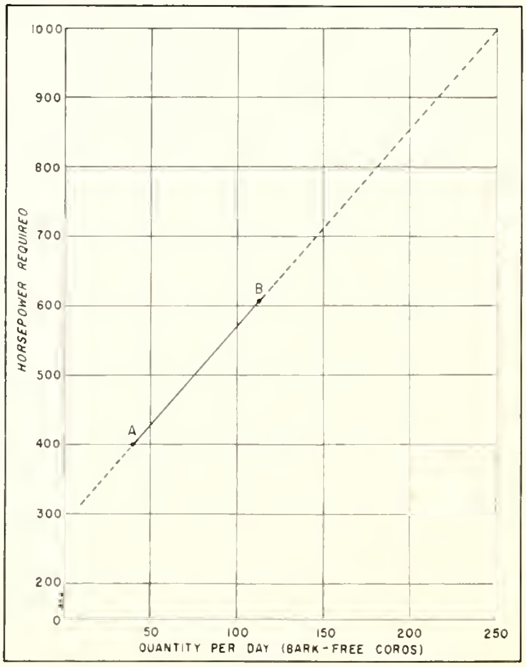
Average horsepower required for mechanical log barkers, by capacity

Mechanical log barker	Daily output	Power requirements
	Bark-free cords	Horsepower
A	5.8	20.0
B	27.5	25.0
C	37.5	60.0

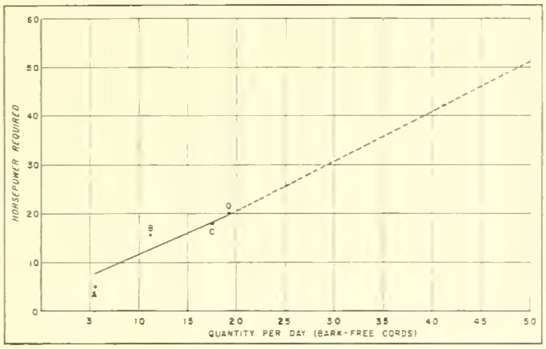


Average horsepower required for hydraulic slab barkers, by capacity

Hydraulic slab barker	Daily output	Power requirements
	Bark-free cords	Horsepower
A	40	400.0
B	112	605.0

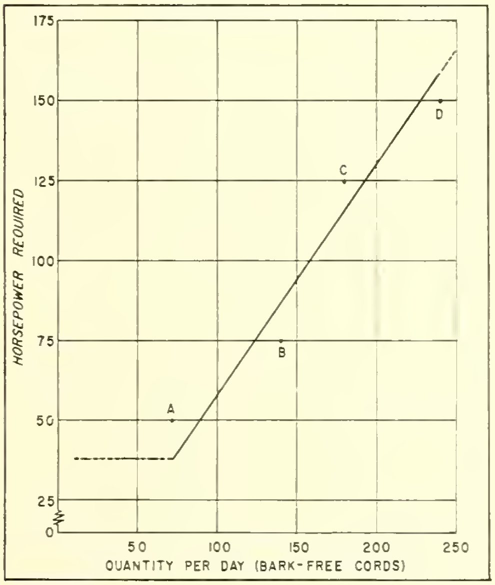


Average horsepower required for mechanical slab barkers, by capacity



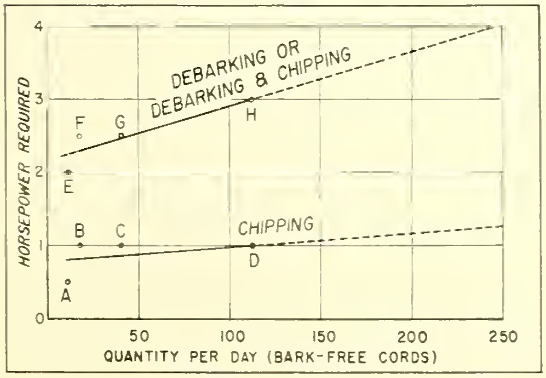
Mechanical slab barker	Daily output	Power requirements
	Bark-free cords	Horsepower
A	5.6	5.0
B	11.2	15.5
C	17.6	18.0
D	19.2	20.0

Average horsepower required for chippers, by capacity



Chipper	Daily output	Power requirements
	Bark-free cords	Horsepower
A	72	50.0
B	140	75.0
C	180	125.0
D	240	150.0

Average horsepower required for three conveyor systems, by capacity



Conveyor system	Daily output	Power requirements
	Bark-free cords	Horsepower
Chipping		
A	11.2	0.5
B	17.6	1.0
C	40.0	1.0
D	112.0	1.0
Debarking or debarking and chipping		
E	11.2	2.0
F	17.6	2.5
G	40.0	2.5
H	112.0	3.0

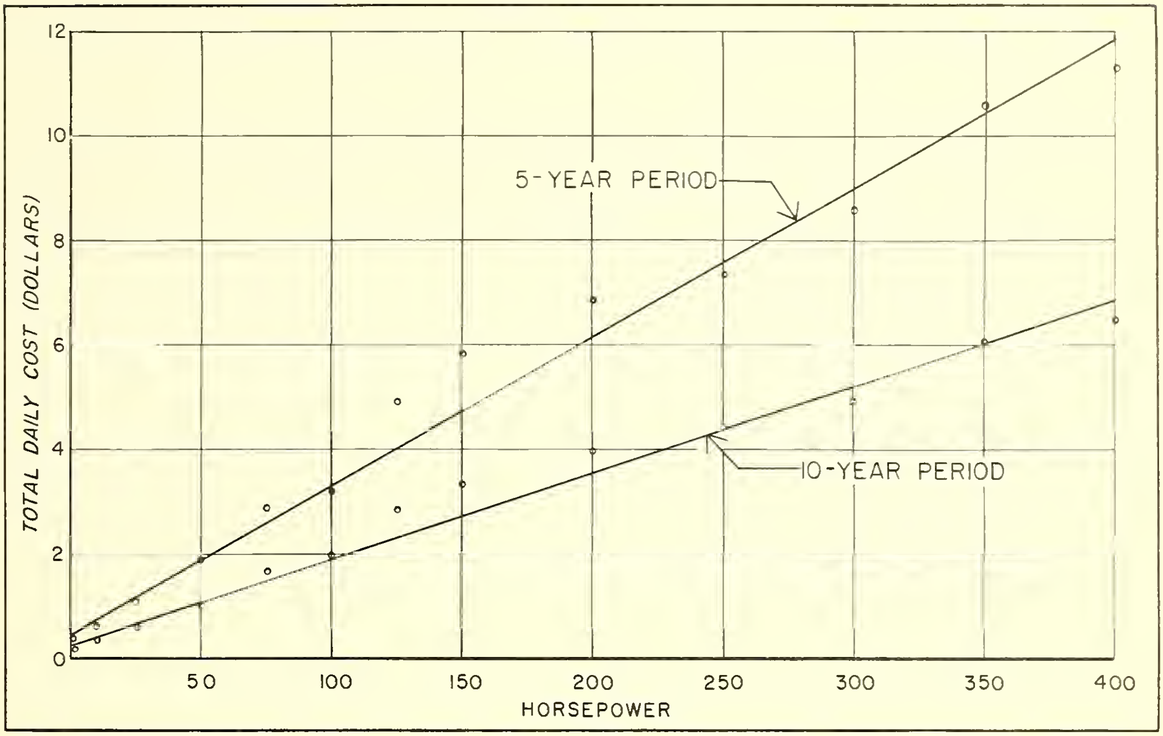
The cost of electric power consists of the expense of the motor and the charge for current to drive it. Electric motor costs were calculated on the basis of both 5- and 10-year depreciation periods. This was done on the perhaps oversimplified assumption that the motor would be discarded with the equipment it powers. Motor prices were obtained from a manufacturer. Prices were for 3-phase, squirrel cage, induction motors with drip-proof enclosures. The motors of 200 horsepower or less operate at approximately 1,800 rpm on 220-, 440-, or 550-volt current, while the larger motors operate at 3,600 rpm on 2,300-volt current. The price of a starter was added to the price of each motor.

In calculating daily cost, no charge for maintenance was included. A motor used only 5 years would be unlikely to have any maintenance cost. Although a motor used 10 years probably would require some maintenance, the cost would be small and difficult to estimate.

Electricity for industrial use is generally sold on two schedules, one for small and one for large consumers. Calculations based on the rates used here show that the small general service schedule results in the lowest cost to customers whose motors total less than 65 horsepower, while the large general service schedule would be advantageous for those using 65 horsepower or more. These are the rates charged by one utility company, but the rates of other companies in the Southeast should be similar.

The rate schedules used in calculating the bill for these two levels of service differ in form. The schedule of rates for small general service is such that it enables the customer to buy additional electricity at lower rates. The large general service customer pays a minimum or demand charge based upon the size of his installation. To this is added a charge for the amount of electricity he uses, which is figured at lower rates than those for the small general service user. Finally, if he is a very large consumer, there is a fuel adjustment which varies the charges with changes in the price of coal.

Daily cost of owning and maintaining electric motors for 5- and 10-year periods (excluding cost of current), by horsepower



5-YEAR PERIOD

	Horsepower												
	1	10	25	50	75	100	125	150	200	250	300	350	400
	Dollars												
Investment													
List price of motor	117	352	653	1,118	1,674	2,145	2,581	3,421	4,370	4,560	5,248	5,858	6,528
Plus list price of starter	195	195	318	446	947	947	1,900	1,900	1,900	2,150	2,664	3,850	3,850
Plus freight	2	7	14	25	38	49	54	59	68	77	86	96	106
Total investment	314	554	985	1,589	2,659	3,141	4,535	5,380	6,338	6,787	7,998	9,804	10,484
Time charges													
Interest at 6 percent on average investment	.05	.09	.16	.25	.43	.50	.73	.86	1.01	1.09	1.28	1.57	1.68
Amortization of investment in 5 years	.28	.49	.88	1.41	2.36	2.79	4.03	4.78	5.63	6.03	7.11	8.72	9.32
Ad valorem taxes	.01	.01	.02	.03	.05	.06	.09	.11	.13	.14	.16	.20	.21
Fire and extended coverage insurance	(1/)	.01	.01	.02	.03	.04	.05	.06	.07	.08	.09	.11	.12
Maintenance	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total cost (for one 8-hour day)	.34	.60	1.07	1.71	2.87	3.39	4.90	5.81	6.84	7.34	8.64	10.60	11.33

10-YEAR PERIOD

	1	10	25	50	75	100	125	150	200	250	300	350	400
Time charges													
Interest at 6 percent on average investment	.05	.08	.14	.23	.39	.46	.67	.79	.93	1.00	1.17	1.44	1.54
Amortization of investment in 10 years	.14	.25	.44	.71	1.18	1.40	2.02	2.39	2.82	3.02	3.55	4.36	4.66
Ad valorem taxes	.01	.01	.02	.03	.05	.06	.08	.10	.12	.12	.15	.18	.19
Insurance	(1/)	.01	.01	.02	.03	.04	.05	.06	.07	.08	.09	.11	.12
Maintenance	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total cost (for one 8-hour day)	.20	.35	.61	.99	1.65	1.96	2.82	3.34	3.94	4.42	4.96	6.09	6.51

1/ Less than ½ cent.

Daily cost of electric current at small general service rate, by total installed horsepower

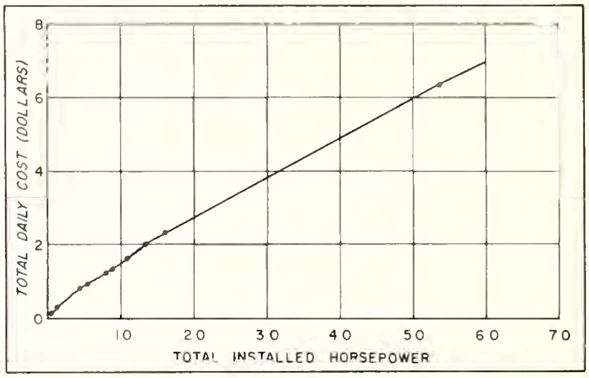
Horsepower	Kilowatts 1/	Kilowatt hours per month	Total cost 2/	
			Month	Day
Hp.	Kw.	Kwh.	- - - Dollars - - - -	
0.5	0.4	55.5	2.05	.11
1.3	1.0	150.0	5.55	.30
2.0	1.5	225.0	7.80	.42
4.5	3.3	500.0	16.05	.86
5.4	4.0	600.0	17.45	.93
8.0	6.0	900.0	23.25	1.24
8.9	6.7	1,000.0	25.72	1.37
10.7	8.0	1,200.0	30.65	1.63
13.4	10.0	1,500.0	38.05	2.03
16.1	12.0	1,800.0	43.45	2.32
53.6	40.0	6,000.0	119.05	6.35
67.0	50.0	7,500.0	144.25	7.69
99.2	74.0	11,100.0	202.57	10.80

1/ 1 hp. = 0.746 kw.

2/ Costs were calculated on the basis of the following monthly rate schedule and adjustments:

$0.037 per kwh for the first 150 kwh
.030 per kwh for the next 350 kwh
.014 per kwh for the next 500 kwh
.010 per kwh for the next 3000 kwh
.007 per kwh for all additional kwh

When, between 150 and 500 kwh, demand exceeds 5 kw, 100 kwh are added for each of the first 5 kw of such excess and 60 kwh for each additional kw of this excess.



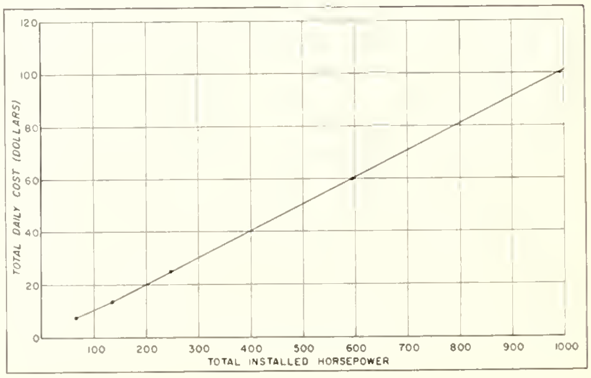
Daily cost of electric current at large general service rate, by total installed horsepower

Horsepower	Kilowatts 1/	Kilowatt hours per month	Total cost 2/	
			Month	Day
Hp.	Kw.	Kwh.	- - - Dollars - - -	
53.6	40.0	6,000	132.00	7.04
67.0	50.0	7,500	142.50	7.60
68.4	51.0	7,650	144.75	7.72
73.7	55.0	8,250	153.75	8.20
99.2	74.0	11,100	196.50	10.48
134.0	100.0	15,000	255.00	13.60
248.0	185.0	27,750	471.11	25.12
595.2	444.0	66,600	1,129.62	60.24
992.0	740.0	111,000	1,882.20	100.38

1/ 1 hp. = 0.746 kw.

2/ Costs were calculated on the basis of the following monthly charges and adjustments:

Demand charge:
$90 per month for first 50 kw.
$1.20 per month for each kw over 50 kw.
Energy charge:
$0.0070 per kwh for first 250,000 kwh per month
.0060 per kwh for 250,000 to 500,000 kwh per month
.0055 per kwh for all kwh over 500,000 kwh per month
Fuel adjustment:
Price of coal at $9 per ton increased net monthly bill by $0.00195 per kwh for each kwh in excess of 15,000 kwh per month

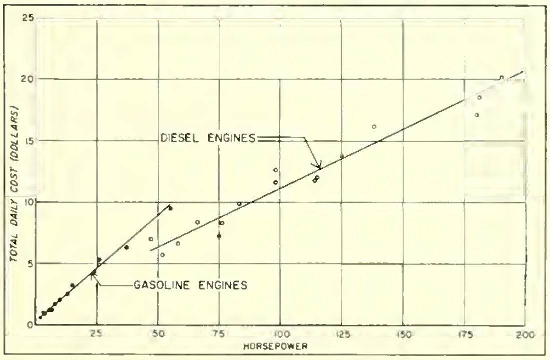


POWER COSTS--INTERNAL COMBUSTION ENGINES

Although daily cost curves for diesel and gasoline engines do not meet within the range of the data, it is obvious that gasoline engines are cheaper to operate at low horsepowers, and diesel engines at higher horsepowers. The break-even point between them is below 50 horsepower.

Price and cost data were obtained for 3 makes and 15 models of gasoline engines, and 3 makes and 17 models of diesel engines. This information was supplied by dealers. Engines were depreciated in 5 years, the period preferred by most users, although dealers suggested a longer interval. Maintenance costs, and oil and fuel consumption were taken from manufacturers' records or calculated on the basis of recommended practices. Gasoline and oil prices are those actually paid by users.

Daily cost of owning and operating gasoline and diesel engines, by horsepower



Gasoline engines

	Horsepower rating (intermittent)														
	2	3	4	6	7	8	8	10	10	13	15	24	26	37	55
	Dollars														
Investment															
List price	68	83	98	107	121	169	188	205	242	247	331	632	343	420	1,013
Freight	5	5	5	5	5	5	5	5	10	10	10	25	10	15	65
Total investment	73	88	103	112	126	174	193	210	252	257	341	657	353	435	1,078
Time charges															
Interest at 6 percent on average investment	.01	.01	.02	.02	.02	.03	.03	.03	.04	.04	.05	.11	.06	.07	.17
Amortization of investment in 5 years	.06	.08	.09	.10	.11	.15	.17	.19	.22	.23	.30	.58	.31	.39	.96
Ad valorem taxes	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	.01	.01	.01	.01	.01	.02
Fire and extended coverage insurance	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	.01	(1)	(1)	.01
Maintenance	.15	.15	.07	.07	.07	.09	.09	.09	.11	.11	.11	.28	.11	.11	.40
Lubricating oil consumption [2]	.13	.20	.07	.07	.07	.10	.10	.10	.10	.10	.10	.08	.10	.10	.18
Fuel consumption [3]	.28	.57	.62	.90	.94	1.34	1.32	1.60	1.54	1.98	2.68	3.34	4.71	5.62	7.75
Total cost (for one 8-hour day)	.63	1.01	.87	1.16	1.21	1.71	1.71	2.01	2.01	2.47	3.25	4.41	5.30	6.30	9.49

[1] Less than ½ cent.
[2] Twenty-five cents per quart.
[3] Nineteen cents per gallon.

Diesel engines

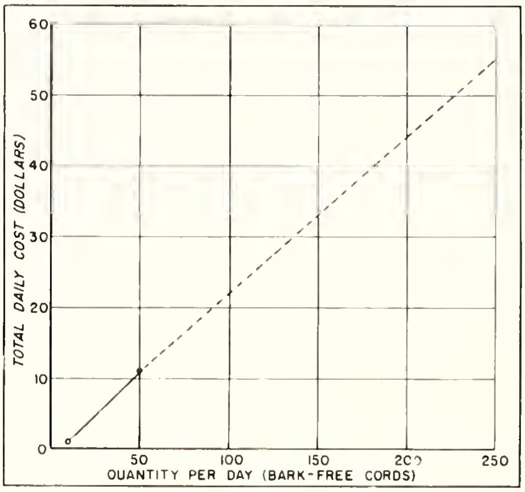
	Horsepower rating (intermittent)																
	47	52	58	66	75	76	83	98	98	114	115	125	138	180	181	190	199
	Dollars																
Investment																	
List price	2,578	2,028	2,450	3,240	2,450	2,984	3,210	4,156	5,062	3,680	3,890	4,545	5,587	4,990	7,118	6,415	6,546
Freight and taxes	130	70	55	120	80	100	70	155	200	90	125	150	175	105	238	220	190
Total investment	2,708	2,098	2,505	3,360	2,530	3,084	3,280	4,311	5,262	3,770	4,015	4,695	5,762	5,095	7,356	6,635	6,736
Time charges																	
Interest at 6 percent on average investment	.43	.34	.40	.54	.40	.49	.52	.69	.84	.60	.64	.75	.92	.82	1.18	1.06	1.08
Amortization of investment in 5 years	2.41	1.86	2.23	2.99	2.25	2.74	2.92	3.83	4.68	3.35	3.57	4.17	5.12	4.53	6.54	5.90	5.99
Ad valorem taxes	.05	.04	.05	.07	.05	.06	.07	.09	.11	.08	.08	.09	.12	.10	.15	.13	.13
Fire and extended coverage insurance	.03	.02	.03	.04	.03	.03	.04	.05	.06	.04	.04	.05	.06	.06	.08	.07	.08
Maintenance	.51	.40	.22	.59	.46	.54	.22	.83	.82	.22	.68	.79	1.02	.22	1.06	1.12	1.28
Lubricating oil consumption [1]	.22	.07	.18	.26	.09	.13	.24	.39	.41	.27	.15	.22	.65	.46	.61	.25	.91
Fuel consumption [2]	3.36	3.01	3.58	3.92	3.99	4.35	5.49	5.71	5.71	7.17	6.90	7.71	8.29	10.98	8.96	11.72	11.31
Total cost (for one 8-hour day)	7.01	5.74	6.66	8.41	7.27	8.34	9.90	11.59	12.63	11.73	12.06	13.78	16.18	17.17	18.58	20.25	20.78

[1] One dollar per gallon.
[2] Fourteen cents per gallon.

OTHER COSTS--SLAB LIFTING EQUIPMENT

Slab lifting equipment costs were calculated for 10-cord-per-day and 50-cord-per-day yards. For the smaller yard, cost was based on the use of a derrick with a hand-operated hoist to unload slabs from trucks. Such a derrick would need a 30-foot mast, a 25-foot boom, and a lifting capacity of 8,000 pounds to make it possible to remove 1½ cords (half a truckload) at a time. The volume that could be handled in this way would be limited by the circumference covered by the boom. Prices for parts and pieces were obtained from published sources. To these were added the estimated cost of assembly. Investment was amortized in 5 years. Maintenance costs were estimated. Slab handling costs at a 50-cord yard were for a lift truck which could move slabs in and out of storage. Price was obtained from a published source for a simple type of lift truck, consisting merely of a hoisting mechanism mounted on a truck chassis. The truck was depreciated in 5 years. Maintenance and fuel costs were derived from published figures. A curve was drawn connecting the point for the 10-cord yard with the one for the 50-cord yard. Projection of this curve over larger outputs was made on the assumption that additional lift trucks would be purchased as yard size increased.

Daily cost of owning and operating slab lifting equipment, by capacity



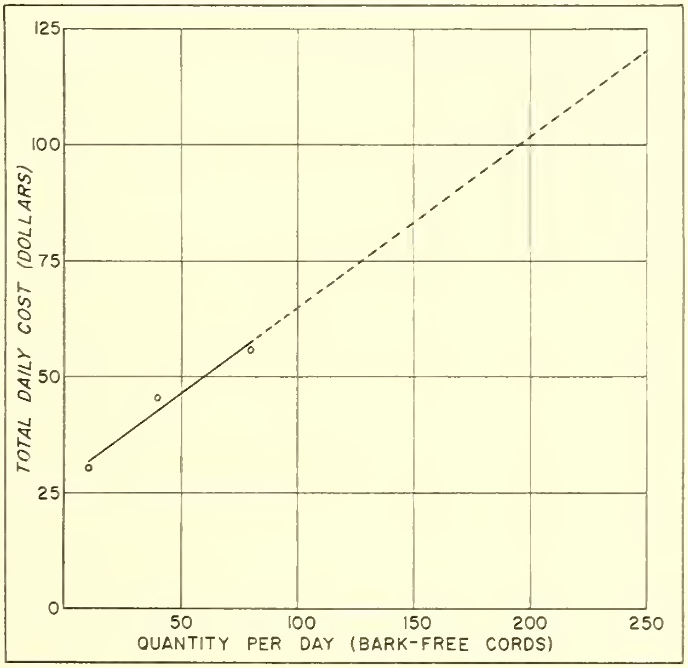
	Capacity (bark-free cords per day)	
	10	50
	Dollars	
Investment		
List price	330	5,285
Freight	10	450
Installation cost	200	00
Total investment	540	5,735
Time charges		
Interest at 6 percent on average investment	0.09	0.92
Amortization of investment in 5 years	.48	5.10
Ad valorem taxes	.01	.11
Fire and extended coverage insurance	.01	.06
Maintenance	.54	3.95
Fuel [1]	.00	.84
Total cost (for one 8-hour day)	1.13	10.98

---

[1] Nineteen cents per gallon.

The cost of additional labor for chipper and complete barker and chipper installations was estimated for three sizes of yards. A 10-cord yard would need 2 additional men and a foreman; a 40-cord yard 2 additional men, a lift-truck operator, and a foreman; and an 80-cord yard 3 additional men, a lift-truck operator, and a foreman. Labor costs are composed of wages and other payments. A minimum wage of $1 an hour was used for unskilled labor; at the other end of the scale, foremen's wages varied with size of yard. The other payments include Social Security, state unemployment compensation, and workman's insurance, which together amount to about 8 percent of wages. The plotted points fall nearly in a straight line. The trend of the line fitted to these points was extended over larger outputs.

Daily cost of additional labor for chipper installation or barker-chipper installation, by capacity



	Capacity (bark-free cords per day)		
	10	40	80
	Dollars		
Time charges			
Wages	28.00	42.00	52.00
Payments for Social Security, state unemployment compensation, and workmen's insurance	2.24	3.36	4.16
Total cost (for one 8-hour day)	30.24	45.36	56.16

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